Review Article

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ELECTROMAGNETIC FIELDS: BIOLOGICAL IMPLICATIONS ON VARIOUS LIFE FORMS

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Abstract: The study of the biological effects associated with exposure to electromagnetic energy at radio-frequency/microwave frequencies is a mature scientific discipline. Exposure to electromagnetic fields has become an issue of concern for great many people and is an active area of biophysical research. It is clear that EMF is not going away from our lives as it has become an integral part. Therefore, it is necessary to give directions to the public, as well as companies involved in the area of EMF. This study confirms that artificial sources of anything are more dangerous than natural sources and opening the door for the acceptance of innovative and beneficial technologies. In the end this review is concluded with intense discussion to devise a strategy to overcome the health hazards posed by EMFs.

Keywords: EMFs, Life forms, Health problems, Phones, Extremely low frequency fields.

INTRODUCTION

The electromagnetic spectrum is defined as the ordered array of known electromagnetic radiations including cosmic rays; gamma rays; X-rays; ultraviolet, visible, and infrared radiations; and radio waves.[1] Life on earth has evolved under the ubiquitous presence of four fundamental forces i.e. gravitation, the weak interaction, the strong interaction and the electromagnetic spectrum. The electromagnetic field (EMF) can be viewed as the combination of an electric field and a magnetic field. Electric field is produced by stationary charges, and magnetic field is produced by moving charges (currents);[2] these two are often described as the sources of the field. On a global basis, electromagnetic fields from natural sources are important contributors in the functional activities of organisms. Besides natural sources, the electromagnetic spectrum also includes fields generated by human-made sources: they have been widely used in clinical practice to promote processes such as neural regeneration and bone repair; X-rays are employed to diagnose a broken limb after a sport accident.[3] The electricity that comes out of every power socket has associated low frequency electromagnetic fields. Various kinds of higher frequency radio waves are also used to transmit information whether via radio stations, TV antennas or mobile phone base stations.[4] Over the past century, this environment has sharply changed with introduction of a vast and growing spectrum of man-made EMF.

During past three decades environmental exposure to man-made electromagnetic fields has been steadily increasing as growing electricity requirement. Ever-advancing technologies and changes in social behavior have created more and more artificial sources.[5] Everyone is exposed to a complex mix of weak electric and magnetic fields, both at home and at work, by means of generation and transmission of electricity, domestic and industrial equipment, to telecommunications and broadcasting.[2] The effects of electromagnetic fields on the human body depend not only on their field level but on their frequency and energy. On the basis of frequencies they are divided into 3 fields: Extremely low frequency (ELF) fields. ELF fields usually have frequencies up to 300 Hz. Intermediate frequency (IF) fields with frequencies from 300 Hz to 10 MHz and radiofrequency (RF) fields with frequencies of 10 MHz to 300 GHz.[6] Since the introduction of wireless telecommunication in the 1990's and rapid industrial and technological developments as well as wide spread application of primary electromagnetic field (EMF) sources such as electric transmission lines, power stations, communication and radio-television signal transmission units has caused a massive increase in electromagnetic pollution in cities and the countryside.[7]

This review encompasses complete information regarding the biological implication of electromagnetic fields on all living forms starting from birds, insects, amphibians, lab animals, plants to humans. Effects were determined by several physiological and immunological indicators i.e. behavior, growth and developmental studies, and the effects on immune system. In the end this review is concluded with intense discussion to devise a strategy to overcome the health hazards posed by EMFs (Figure 1).

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Question over effects of EMF

Modern technology has introduced electromagnetic fields with frequency signatures unfamiliar to the planet's organisms. Where once sunlight and its lunar reflections provided the bulk of the visible spectrum (with fire and lightening a distant second), now, many alternatives of artificial light have complemented or replaced the sun as the main supplier. In addition, EMF from other parts of the spectrum has become ubiquitous in daily life. In the last two or three decades, health concerns have been raised about EMF exposure from 1) mobile communication devices, 2) occupations, 3) residences, and 4) all other transmission sources.

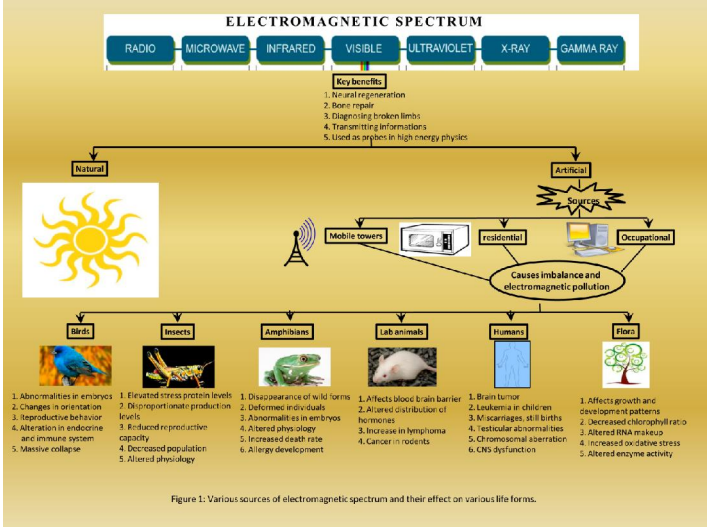

Figure 1: Various sources of electromagnetic spectrum and their effect on various life forms.

The electromagnetic fields have many positive effects of on health, for example some studies proved that ELF-EMF modulates chemokine production and keratinocyte growth through inhibition of the NF-kappa B signaling pathway and thus may inhibit inflammatory processes. In another study Vianale *et al.*,[8] showed that ELF-EMF could augment the cell apoptosis effects of low doses of (radiotherapeutic) X-ray irradiation on (liver cancer cell line) BEL-7402 cells in a synergistic and cumulative way. On the other hand, Wen *et al.*,[9] characterize ELF-EMF as potentially harmful and possible carcinogens to humans and some data suggest that they can act as promoters or progressors.[10] Li *et al.*,[11] provided some evidence that EMF exposure may have an adverse effect on sperm quality. There are many cited papers which focus on the value of mobile communications for telemedicine and patient monitoring. Their references cover cell phones, examining many different varieties. They indicate that if the cell phones are kept at a reasonable distance from the implant, they will not cause interference. While most documents concluded that EMF decreased reaction times and promoted sleep, with an increase in suicides with exposure.[12] In another study Koivisto *et al.*,[13] concluded that exposure to the electromagnetic field emitted by cellular telephones may have a facilitator effect on brain functioning, particularly in tasks requiring attention and manipulation of information in working memory.

There is also a big link between the long-term use of mobile phones and the risk for brain tumors, with one such study that examined, parotid gland tumors, and saw increased association with ipsilateral (same side) heavy cell phone use. Many studies and researches tended to be in association of childhood cancers (mainly leukemia) with magnetic field exposures. A study of tumor cases reported in the county of Stockholm for individuals 0-18 years of age concluded that magnetic fields of 0.3 microT or more were found twice as frequently among cases as among controls.[14] While the results are mixed, there appears to be more agreement that occupational exposures to EMF are associated with increased cancer risk than mobile phones are associated with increased tumor risks.

Effect on animals

I. *Birds, Insects, Amphibians, Non-Mammalian Species:* Delgado *et al.*,[15] reported that weak pulsed ELF magnetic fields [0.12 to 12 mT; 10, affected the early development of chicken embryos examined after 48 h of incubation. After this initial finding, the same research group published several papers reporting similar effects.[16,17] In the experiments of Juutilainen *et al.*,[18], the percentage of abnormalities was increased in chick embryos exposed during their first two days of development to 100 Hz magnetic fields with pulsed, sinusoidal and rectangular waveforms. In another series of experiments with sinusoidal waveform, comparable effects were found in a wide range of frequencies.[19] Farrell *et al.*,[20] conducted an extensive series of experiments on the effects of pulsed and sinusoidal magnetic fields on chick embryo development, involving a total of more than 2500 embryos. Both 60 Hz, 4mT sinusoidal fields and a 100 Hz field with 1 mT peak amplitude, similar to the field used in the Henhouse study, were used. Overall, the abnormality rate was more than doubled by the magnetic fields, and the effect was statistically significant for both 100 and 60 Hz fields. Quail embryo development has also been reported to be affected by exposure to ELF magnetic fields.[21] The exposures were 50 or 100 Hz with rectangular waveform and intensities of 0.2, 1.2, 3.3, and 3.2 mT, and the embryos were examined at 48 hour.

European Robins were tested in cages to determine if magnetic pulses and light of various wavelengths influenced orientation.[22] Robins submitted to a brief magnetic pulse (designed to alter the magnetization of single domain magnetite) after being tested with different wavelength light regimes. The magnetic pulse altered migration orientation with birds tested in white and green light being able to orient accurately but birds tested in red light (633 nm) could not orient.[22] One study that really addressed the influence of short-wave radio waves on Homing Pigeons was performed by Bruderer and Boldt.[23] A long-term exposure to microwave radiation especially from 3G GSM (Global System for Mobile Communications) digital-phone technology is killing the birds. Scientists (at the Research Institute for Nature and Forests, Brussels, Belgium) have produced the first evidence that mobile phone base stations are affecting the reproductive behaviour of wild sparrows. This discovery comes as mobile phones are held suspect in the massive collapse of bee colonies all over the United States and Europe. The sparrows (*Passer domesticus*) have also disappeared completely from the cities at least four years ago in Britain, as mobile phones grew in popularity.[24] Fewer house sparrow males were seen at locations within relatively high electric field strengths of GSM base stations.[24] Alfonso Balmori, a conservation biologist in Spain, reported a significantly lower number of white stork (*Ciconia ciconia*) fledglings in nests close to mobile phone transmitters compared to nests further away.[24] Balmori also found difference in how the birds behaved close to the phone antennae. He noticed that young birds died from mysterious causes, and bird couples repeatedly fought while constructing their nests. Several nests were never completed and the storks remained passively near antennae.[25,26]

However, 15 of the 35 species of European bat have been recorded as regular victims of turbine collisions, and an Inter sessional Working Group of Eurobats listed 20 species thought to be at risk of collision due to their foraging and commuting behavior.[27] It has been suggested that the radio frequency (RF) radiation associated with radar installations could potentially exert an aversive behavioral response in foraging bats.[28] It is also possible that the electromagnetic radiation from the radar may not be affecting bats directly but rather the insects upon which they feed. Bat activity within an area is strongly correlated with insect density.[29,30] therefore any reduction in insect density would result in a concurrent reduction in bat activity.

EMFs have altered the endocrine and immune systems of birds.[31] Circulating levels of corticosterone and anti-thyroglobulin antibodies were markedly suppressed in young chickens continuously exposed to EMFs that would be lower than those experienced by wild birds.[32] Much more research has focused on the effects of EMFs on melatonin, produced by the pineal gland, elevated under dark conditions but suppressed by light.[31] For birds, the suppression of melatonin through EMF exposure may alter other circannual [e.g., reproduction, migration, seasonal metabolism][33-35] and circadian rhythms [e.g., physiology, locomotor activity, feeding, sleeping] critical to survival.[36] Furthermore, melatonin also is associated with plumage color changes[37], is important in mate selection in birds[38,39], plays a key role in the growth and development of young birds[40], and acts as an antioxidant and free radical scavenger relating to oxidative stress.[41]

The microwaves may affect the insects. Insects are the basis and key species of ecosystems and they are especially sensitive to electromagnetic radiation that poses a threat to nature.[42] Carpenter and Livstone[43] irradiated pupae of *Tenebrio molitor* with 10 GHz microwaves at 80 mW for 20–30 min and 20 mW for 120 min obtained a rise in the proportion of insects with abnormalities or dead. In another study exposing fruit flies (*Drosophila melanogaster*) to mobile phone radiation, elevated stress protein levels (Hsp70) was obtained, which usually means that cells are exposed to adverse environmental conditions (non-thermal shock).[44] A decrease of insects and arachnids near base stations was detected and corroborated by engineers and antenna's maintenance staff.[45] In houses near antennas an absence of flies, even in summer, was found. In a study, effect of GSM (Global System for Mobile telecommunications) 900 MHZ and DCS (Digital Cellular System) 1800 MHZ was monitored on reproductive capacity of *Drosophila melanogaster*. Both types of radiation were found to decrease significantly and non-thermally the insect's reproductive capacity, however, GSM 900MHz seems to be even more bioactive than DCS 1800 MHz. The variation seems to be dependent mostly on field intensity and less on carrier frequency.[31]

Disappearance of amphibians and other organisms is part of the global biodiversity crisis. An associated phenomenon is the appearance of large numbers of deformed amphibians. The problem has become more prevalent, with deformity rates up to 25% in some populations, which is significantly higher than previous decades.[46] Balmori[45] proposed that electromagnetic pollution (in the microwave and radiofrequency range) is a possible cause for deformations and decline of some wild amphibian populations. Two species of amphibians were exposed to magnetic fields at various stages of development. A brief treatment of early amphibian embryos produced several types of abnormalities.[47] Exposure to a pulsed

electromagnetic field produced abnormal limb regeneration in adult Newts.[48] Frog tadpoles (*Rana temporaria*) developed under electromagnetic field [50 Hz, 260 A/m] have increased mortality. Exposed tadpoles developed more slowly and less synchronously than control tadpoles and remain at the early stages for longer. Tadpoles developed allergies and EMF caused changes in blood counts.[49]

II. Lab animals: Extremely low frequency magnetic fields (ELF-MF) have the ability to produce a variety of behavioral and physiological changes in animals.[50] The stomach, as the sensitive part of the neuroendocrine organ of the gastrointestinal tract, is important for the initiation of a full stress response against all harmful stress. The exposure to ELF-MF (durations of 24 h and 1 or 2 weeks, 60 Hz frequency, 0.1mT intensity) altered the distribution and occurrence of ghrelin, gastrin and somatostatin-positive endocrine cells in the stomach of rats. However, the change in the secretion of those hormones into blood from endocrine cells did not appear significantly with ELF-MF exposure.[50] Hong *et al.,* studied the influence of exposure to extremely low frequency magnetic field on neuroendocrine cells and hormones in stomach of rats. Rats were continuously exposed to 60 Hz magnetic field for 7 days.

Immuno-histochemical staining was done and the expressions of ghrelin, gastrin and somatostain positive cell in gastric tissue were detected with the avidin-biotinylated horseradish peroxidase complex. In order to evaluate the effect of ELF-MF on gastrointestinal motility, BaSO4 suspension propelling ratio was measured. The results suggest that changes of the hormonal function of the stomach can occur in rats subjected to the exposure to ELF-MF. However, the change in the secretion of those hormones into blood from endocrine cells did not appear significantly with ELF-MF exposure.

Dragicevic *et al.,*[51] showed that long-term exposure to high frequency electromagnetic field (EMF) treatment not only prevents or reverses cognitive impairment in Alzheimer's transgenic (Tg) mice, but also improves memory in normal mice. To elucidate the possible mechanism(s) for these EMF-induced cognitive benefits, brain mitochondrial function was checked in aged Tg mice and non-transgenic (NT) littermates following 1 month of daily EMF exposure. In Tg mice, EMF treatment increased brain mitochondrial function by 50–150% across six established measures, being maximum in cognitively-important brain areas (e.g. cerebral cortex and hippocampus). Interestingly, EMF treatment also increased brain mitochondrial function in normal aged mice, though the enhancement was not as robust and less widespread compared to Tg mice. The EMF-induced enhancement of brain mitochondrial function in Tg mice was accompanied by 5–10 fold increases in soluble Aβ1-40 within the same mitochondrial preparations. These enhancements in mitochondrial soluble amyloid-β peptide (Aβ) were apparently due to the ability of EMF treatment to disaggregate Aβ oligomers, which are thought to be the form of Aβ causative to mitochondrial dysfunction in Alzheimer's disease (AD). Finally, the EMF-induced mitochondrial enhancement in both Tg and normal mice occurred through non-thermal effects because brain temperatures were either stable or decreased during/after EMF treatment.[51]

In another study, the effects of mobile phone electromagnetic fields (EMFs) were studied on a non-spatial memory task (Object Recognition Task-ORT) that requires entorhinal cortex function.[52] The task was applied to three groups of mice *Mus musculus* C57BL/6. The ORT-derived discrimination indices in all exposures revealed a major effect on the "chronic exposure-I" suggesting a possible severe interaction of EMF with the consolidation phase of recognition memory processes. This may mean that the primary EMF target may be the information transfer pathway connecting the entorhinal–parahippocampal regions which participate in the ORT memory task.[52]

Microwaves may affect the blood brain barrier which lets toxic substances pass through from the blood to the brain.[53] Adang *et al.,*[54] examined the effect of microwave exposure to a GSM-like frequency of 970MHz pulsed waves on the memory in rats by means of an object recognition task. The rats that have been exposed for 2 months show normal exploratory behavior. The animals that have been exposed for 15 months show derogatory behavior.

III. Effect on Humans: Basic scientific study of the human body has demonstrated that most physiological functions in living organisms are electrochemical in nature.[55] Living cells are made up of molecules and atoms, which consecutively are made up of electrons, protons and neutrons. The intrinsic functioning of these atoms and molecules with homeostasis of cells, tissues and organs is completely dependent on ordered chemical and electrical activity. Therefore, disturbance of intrinsic electrical or chemical processes within cell structures has the potential to disrupt cell functioning which leads to malfunction of organ systems and ultimately to clinical illness.[55]

With the multiple functions the cell phones have captured great importance in the life of modern man but the latest studies say that we are carrying a silent killer with us. It is proved that the radio

frequency (RF) which is a kind of electro-magnetic radiation has ill effects on the human body. The same radio frequency is emitted from the cell phones and cordless phones but with lower frequency. Radio waves from mobile phones harm body cells and damage DNA in laboratory conditions, according to a new study majority-founded by the European Union, researchers. WHO now admits that mobile phones may increase the risk for brain tumors A working group of 31 scientists from 14 countries meeting at the WHO's International Agency for Research on Cancer IARCL believed a review of all the available scientific evidence suggested cell phone use should be classified as "possibly carcinogenic".[56]

In a preliminary study publishes in Science Daily (Feb. 22, 2011), researchers found that 50-minute cell phone use was associated with increased brain glucose metabolism (a marker of brain activity) in the region closest to the phone antenna, but the discovery is of unknown clinical significance. A mobile phone's main source of RF energy is its antenna, so the nearer the antenna is to a phone user's head, the greater the person's exposure to RF energy.[57] Reasons for different RF absorption or SAR in children's and adults' heads could stem from differences in head sizes, tissue sizes, and dielectric properties of the tissues. A thinner skull could for example be a reason for deeper field penetration in the head. However, contradictory results have been found in simulation studies.[58] Some research groups found an important SAR increase in children's head with respect to adults'[59] while other groups do not find any relevant differences.[60] Since the child's ear is less elastic and thinner, the mobile phone pressed against it could come closer to the brain and an increased absorption in the brain could result. The position of the mobile phone with respect to the head and the antenna model are critical parameters in simulation programs and may account for the differences in SAR results.

Incubation of human peripheral blood cultures in the presence of an electromagnetic field (EMF) of 50 Hz and 5 mT leads to stimulation of the cell cycle of dividing lymphocytes but has no influence on the frequencies of sister-chromatid exchanges.[61] Comparative studies with two special exposure systems and with different culture temperatures indicate that the effect on the cell cycle results from the EMF and is not a thermal effect.[61]

In 2002, the International Agency for Research on Cancer (IARC) categorized extremely low frequency (ELF) (including the power frequencies of 50 and 60 Hz) magnetic fields as "possibly carcinogenic to humans. In 2007 a task group of scientific experts convened by the World Health Organization (WHO) acknowledged the IARC categorization but found that the laboratory studies and other research results did not support the association. Taking all facts into account WHO reported that it could not confirm the existence of any health consequences from exposure to low-level magnetic fields.[62] There remains continuing concern by some people that exposure to power frequency magnetic fields may cause adverse health effects, particularly childhood leukemia.[62]

A recent study revealed that children exposed to1800 MHz cell phone electromagnetic fields [EMF's] can experience significantly higher exposure to cortical regions, hippocampus, hypothalamus and the eye than the adults and that this difference can be greater than one order of magnitude. The most feared brain tumors in adults and children are 'the gliomas', which include astrocytomas and oligodendrogliomas. These tumors are graded on a progressive scale of malignancy, and astrocytomas that have progressed to Grade IV World Health Organization [WHO] classification level are also known as "glioblastomas", which are common brain tumors and most frequently arise as de novo as primary cancers.

EMFs and reproductive dysfunction

Adverse pregnancy outcomes including miscarriage, preterm delivery, stillbirth, altered gender ratio and congenital anomalies have all been linked to maternal EMF exposure.[63-65] A large prospective study published in Epidemiology, reported on peak EMF exposure in 1063 pregnant women around the San Francisco area. Once participants wore a magnetic field detector, the researchers discovered that rates of pregnancy loss increase significantly with increasing levels of maximum magnetic field exposure in routine day-to-day Life.[65] Paternal EMF exposure has also been correlated. The development of testicular abnormalities, atypical sperm, chromosomal aberrations and offspring congenital defects have all been linked to male EMF exposure.[66,67] Vignera La *et al.,*[68] suggested that mobile phone use alters sperm parameters in both experimental animals and humans. Sperm motility and morphology seem to be the 2 parameters more frequently affected. They provided evidence that mobile phone radiation results in increased oxidative stress, with subsequent sperm membrane lipid and DNA damage. These abnormalities seem to be directly related to the duration of mobile phone use.

EMFs and cancer

Numerous studies have investigated the allegation that intense exposure to some frequencies of EMR may be carcinogenic. By assessing magnetic field levels in children's bedrooms, the researchers established that high EMF exposure was associated

with a significantly higher risk of childhood leukaemia.[69] Furthermore, studies reported in major journals such as The Lancet and International Journal of Oncology discuss the apparent link between cordless and cellular phone use with conditions such as lymphoma[70], malignant and benign brain tumours[71,72], as well as other problems including alterations in blood pressure.[73]

EMFs and CNS dysfunction

The CNS appears to be a potential target organ system for adverse EMR. Besides reports of specific EMF-related health problems, such as amyotrophic lateral sclerosis[74], Alzheimer's disease[75], insomnia76, headaches[77], sexual dysfunction[78], chronic fatigue[76], learning and memory problems[79-81], and assorted other maladies[82,83], there is increasing evidence to suggest that neuropsychiatric problems may also result from EMR. Higher rates of suicide and depressive symptoms have been found to result from EMF exposure.[74,84-86]

Particular attention, however, has recently been devoted to researching the impact of EMR on pineal gland physiology.[87] The pineal gland secretes the neuroendocrine hormone melatonin that is synthesized from the neurotransmitter serotonin. Melatonin is involved with regulation of myriad physiological processes including sleep patterns[88], free radical metabolism[89], blood pressure control[90], nitric oxide physiology[91], lipid metabolism[92], immune system functioning[93], and activity of sex hormones such as oestrogen.[94] It was previously thought that thermal alteration of cells and tissue heating may be the predominant mechanism of harm. However, increasing evidence has indicated the potential of EMR to induce cell stress[95] and to inflict specific damage on various intracellular components and mechanisms at non-thermal levels of EMF exposure.[92] For example, molecular vibrations from EMR may induce free radical formation and alter the conformation of protein molecules.[4] Adverse EMR has been found to affect DNA synthesis, cell division and to potentially alter the electrical charge of ions and molecules within cells.[66]

IV. *Effect on plants:* Electromagnetic fields are an important environmental factor that can influence the growth and development of plants. Plants react in a multitude of ways to geomagnetic fields, strong continuous fields as well as alternating magnetic fields. In the past, physiological investigations were pursued in a somewhat unsystematic manner and no biological advantage of any magnetoresponse is immediately obvious. As a result, most studies remain largely on a phenomenological level and are in general characterised by a lack of mechanistic insight, despite the fact that physics provides several theories that serve as paradigms for magnetoreception.[96] The microwaves may affect vegetables. In the area that received radiation directly from "Location Skrunda Radio Station" [Latvia], pines (*Pinus sylvestris*) experienced a lower growth radio. This did not occur beyond the area of impact of electromagnetic waves. A statistically significant negative correlation between increase tree growth and intensity of electromagnetic field was found, and was confirmed that the beginning of this growth decline coincided in time with the start of radar emissions.[97]

In another study investigating cell ultra-structure of pine needles irradiated by the same radar, there was an increase of resin production, and was interpreted as an effect of stress caused by radiation, which would explain the aging and declining growth and viability of trees subjected to pulsed microwaves. They also found a low germination of seeds of pine trees more exposed.[98] Chlorophylls were quantitatively studied in leaves of black locust (*Robinia pseudoacacia L.*) seedlings exposed to high frequency electromagnetic fields of 400 MHz. It was revealed that the ratio of the two main types of chlorophyll was decreasing logarithmically to the increase of daily exposure time.[99] Exposed tomato plants (*Lycopersicon esculentum*) to low level (900 MHz, 5 V/m) electromagnetic fields for a short period (10 min) measured changes in abundance of three specific mRNA after exposure, strongly suggesting that they are the direct consequence of application of radio-frequency fields and their similarities to wound responses suggests that this radiation is perceived by plants as an injurious stimulus.[100]

EMFs in both extremely low frequency (ELF) and radio frequency (RF) ranges activate the cellular stress response which is a protective mechanism that induces the expression of stress response genes.[101] A potential link between EMFs and its effects on living organisms is the fact that EMFs cause an oxidative stress that is, increase in the activity, concentration and lifetime of free radicals.[102-104] Accordingly, EMFs alters protein biosynthesis, gene expression, enzyme activity, cell reproduction and cellular metabolism.[105] EMFs cytological effects include changing the mitosis control mechanisms, increase in the percentages of chromosomal aberrations such as stickiness, lagging and disorganized chromosomes.[106] Maize [*Zea Maize*] plants pretreated with 3 and 10 mT for 4 h exposure time, also showed less growth.[102]

For some years progressive deterioration of trees near phone masts have been observed in Valladolid (Spain). Trees located inside the main lobe (beam), look sad and feeble, possibly slow growth and

a high susceptibility to illnesses and plagues. In places we have measured higher electric field intensity levels of radiation (>2 V/m) the trees show a more notable deterioration.[107] The tops of trees are dried up where the main beams are directed to and they appear to be most vulnerable if they have their roots close to water. The trees don't grow above the height of the other ones and, those that stand out far above, have dried tops (Hargreaves, personal communication and personal observation). The inhibitory effect of EMF radiation on root growth of mung bean (*Vigna radiate*) has recently been investigated.[108] Significant inhibition of root growth was observed as a result of the application of a cell phone electromagnetic field by inducing reactive oxygen species-generated oxidative stress in a time-dependent manner.[109] Duckweed (*Lemna minor* L.) was exposed to EMF for two hours to investigate the physiological response of the plant. Oxidative stress was induced, especially at 900 MHz, by exposure of the duckweed to non-thermal exposure to radiofrequency fields, probably due to the effect on anti-oxidative enzyme activities.[110]

Concluding remarks and future perspective

Although the outcomes of various studies performed on all life forms have provided convincing evidence of an association between exposure to electromagnetic fields and the development of certain health problems yet, the biological effect is not the same for every individual exposed, but yes, every individual is altered in some or the other fashion related to them. These effects slowly kill the character on many levels, which it is unaware of. Sadly, modern medicine is not also alert of this danger. It is clear that EMF is not going away in our life time because both industry and governments, along with us, clearly desire it in large quantities for their productivity and modern lifestyles. Thus, use of shielding devices on computer screens, cellular phones and other EMF generating machines is essential. Governments have to aware their people about adding shielding to household wiring, circuit box, and transformers. Use of shielding-enhanced materials in the bedding or clothing should be done if one must be exposed to EMFs.

It is clear that there is a need for a continuous research, carefully directed toward answering the questions raised by previous work. A proper (clear) layout of guidelines is thus awaited from the scientific community at large and regulatory authorities in particular to give direction to public as well as companies involved in this area. In the end, until a realistic risk assessment can be performed and an appropriate societal or regulatory response is initiated, the responsibility lies with each individual to learn more about their electromagnetic environment and to exercise a degree of caution consistently with their own approach to uncertain risks.

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